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REMARKS

In order to promote administrative efficiency and better communication, the Examiner is invited to make suggestions at any time during the proceedings, via phone, fax or e-mail, whenever such suggestions are within the Examiner's discretion as an aid to placing the claims in order for allowance in a timely manner.

Election/Restrictions:

On this point, Applicant wishes to correct the record. Claims 18-*23* , not 18-22, are withdrawn, without prejudice, from further consideration. New claim 23 was added by pre-amendment at the time of the filing of the application.

Specification:

The abstract has been placed in narrative form and does not exceed 15 lines of text. A replacement abstract is attached.

Claim Objections:

Claim 5 is cancelled without prejudice. Consequently, this objection is moot.

Claim Rejections §103(a) Rejection based on Rosenblad:

Examiner's Points 5 and 6:

The Examiner rejected claims 1, 3, 4, 5, 7, 8, 14, 15, and 17 under 35 U.S.C. §102(b) as being anticipated by, or in the alternative, obvious over Rosenblad et al. Claim 5 is cancelled to this rejection is moot with respect to this claim. As for the remaining claims, Applicant has amended claim 1 for clarity. The method claim now is concerned with the

"forming of a heterostructure semiconductor device". Claim 1 now requires that a silicon substrate is used. This limitation is supported by sections [0039] [0053] of the published specification. Here, it is clear that the substrate temperature is kept constant during the formation of the $Si_{1-x}Ge_x$ semiconductor layer. Further, the semiconductor layer is now called $Si_{1-x}Ge_x$ semiconductor layer. In this context, it is also claimed that the respective $Si_{1-x}Ge_x$ semiconductor layer has a thickness between 100nm and 800nm. Support for this is given at sections [0045], [0048], [0049] of the published specification and in original claim 10 (now cancelled). The Germanium concentration has been amended to require that it is constant. This amendment is supported by the application as filed, see for example paragraph [0068] or claim 18 as filed. Two further method steps have been added which are important for the formation of the heterostructure semiconductor device. Still further, a specifically optimized annealing step is performed in order to ensure that the surface roughness (rms) of said $Si_{1-x}Ge_x$ semiconductor layer is below 1.8nm. The temperature range between 600^0C and 870^0C is disclosed in sections [0032], [0047], [0060], and [0076], as well as in original claim 16 (now cancelled). The roughness is disclosed in sections [0063], [0065], and in original claim 12. Finally, in a subsequent step the active region is formed. Support for this amendment is found in paragraphs [0029], [0047], and [0069] of the published application.

Concerning the Examiner's argument that claims 1, 3 - 8, 14, 15 and 17 are obvious over Rosenblad et al., although Rosenblad et al. (11-14) ("Rosenblad 1") does indeed disclose a method for forming epitaxial SiGe layers, all layers described in this reference apply, however, to *strained* layers. Even though this is not mentioned explicitly in Rosenblad 1, this is evident from Figs. 2 and 4 which demonstrate that all interfaces are free from dislocations, which means that the SiGe layers necessarily have to be strained. In fact, Rosenblad 1 describes SiGe/Si superlattices coherently strained (pseudomorphic) to the Si(001) substrate (Fig. 4). The teachings of Rosenblad 1 are therefore not applicable to the present invention, in which a high degree of relaxation is explicitly claimed in claim 1. It cannot fairly be said that the method described by Rosenblad 1 is suitable also for the fabrication of highly relaxed layers, and so, Rosenblad 1 cannot be said to make the amended claim 1 obvious. It is neither obvious that highly relaxed layers with Ge concentrations in between $0\% < x < 50\%$ can be realized at substrate temperatures between 350° C and 500° C, because achieving a high degree of relaxation requires other physical mechanisms to prevail than pseudomorphic growth at a higher temperature of 550° C. In the extensive literature cited in the application

(Chen et al., J. Appl. Phys. 79 (1995) 1167; Kasper et al., Thin Solid Films 336 (1998) 319; Kuchenbecker et al., Thin Solid Films 389 (2001) 146, etc.) point defects formed at very low substrate temperatures have been shown to provide such a mechanism. It cannot be said to be obvious that the high rates of between 1 and 10 nm/s, combined with substrate temperatures in the range of 350° C to 500° C (claim 1) would lead to similar or even better results , especially in the absence of a subsequent growth or annealing step carried out at higher T.

Examiner's Point 7:

The Examiner has rejected claims 1 and 9 as being obvious over Rosenblad et al. "Epitaxial growth at high rates with LEPECVD", Thin Solid Films 336 (1998) pp. 89-91 ("Rosenblad 2"). Rosenblad 2 teaches, however, the growth of thick (4.1 μm) graded layers at a substrate temperature of 575° C. Compositional grading at low grading rates (5%/ μm) has been shown to result in highly relaxed layers as described by Fitzgerald et al., Appl. Phys. Lett. 59 (1991) 811 (erroneously cited in the application with the incorrect volume number (58 instead of 59)), provided that the substrate temperature is sufficiently high for relaxation to occur. By contrast, the present invention teaches the growth of much thinner (100 to 800 nm) layers of constant composition with a high degree of relaxation at low substrate temperature (350° C – 500° C). From Rosenblad 2, it cannot be said to be obvious that a high degree of relaxation can be achieved for constant-composition layers grown to much lower thicknesses at substantially lower substrate temperature.

Examiner's Points 8 and 9:

The Examiner has rejected claims 6 and 13 as being unpatentable over Rosenblad 1. The high substrate temperature of 700° C – 750° C claimed in the invention is not an obvious extension from the 600° C described by Rosenblad 1. In fact, the high formation temperature for the Si buffer ensures a low point defect density in this layer (e.g., Kasper et al., Thin Solid Films 336 (1998) 319 cited in the application), so that the subsequent achievement of high relaxation at low substrate temperature must be considered to be even more surprising.

Applicant asserts that Rosenblad 1 is not applicable to claim 13, because the former concerns a strained (pseudomorphic) SiGe/Si superlattice and not a highly relaxed layer. A

germanium concentration in the range of $50 < x < 100\%$ would never have been considered by one having ordinary skill in the art, because at these high concentrations pseudomorphic growth (as described by Rosenblad 1) would have been considered impossible, and in fact is, at the substrate temperature and layer thicknesses described by Rosenblad 1.

Examiner's Point 10:

The Examiner has rejected claims 2, 10-12 as being unpatentable over Rosenblad 2. Applicant traverses this rejection. Rosenblad 2 refers to thick, graded SiGe alloy layers grown at substrate temperatures high enough (575° C) for relaxation to occur during growth. For 4 μm thick layers to be grown in less than 4 min, the growth rate would have had to be at least 16 nm/s, i.e., far outside the 1.8 nm/s stated on p. 90, second column of Rosenblad 2.

With regards to claim 12, it should be emphasized that it is well known that grading is characterized by considerable surface roughness caused by the so-called cross-hatch (e.g., Rosenblad 2), and this roughness increases with increasing layer thickness. It therefore cannot fairly be said that obtaining a surface roughness of less than 1.8 nm is obvious. Especially for grading to higher Ge concentrations (and much larger layer thickness), the surface roughness according to the teaching of Rosenblad 2 would have been even higher than the 2.8 nm reached for a final Ge content of only 20%.

Examiner's Point 11:

The Examiner has rejected claim 16 as being unpatentable over Rosenblad 1 in view of Hackbarth et al. Applicant traverses this rejection. The annealing step described by Hackbarth et al. at 800° C has a completely different purpose than the annealing step of claim 16. Hackbarth et al. use this annealing step only to remove the surface oxide on graded buffer layers. Graded buffer layers do not require an annealing step to help relaxation because they are always grown at sufficiently high temperature for relaxation to be close to 100% during growth. By contrast, the annealing step of claim 16 is carried out in order to increase further the degree of relaxation of the relaxed constant-composition layer claimed in claim 1.

In sum, Applicant disagrees that the invention as now claimed is not patentable, primarily because it is Applicant's view that the prior art cited is not particularly relevant to the now claimed invention. Claim 1 as amended is clearly novel and considered to be non-obvious because none of the combinations of the prior art documents anticipates the invention, as claimed, or teach or suggest the invention as claimed. Applicant considers that it is not obvious to reduce the buffer thickness to below 1 micron, while still achieving a high degree of relaxation. It is even less obvious that substrate temperatures can be lowered while maintaining the high growth rates as stated in claim 1.

Further, none of the prior art documents discloses a method for forming a highly relaxed semiconductor layer with a thickness between 100 and 800 nm in an LEPECVD system. In order to further distinguish the method of claim 1 from the prior art, this claim has been limited, so that the Germanium concentration is a <u>constant</u>, i.e. not a graded layer. This amendment is supported by the application as filed, see for example paragraph [0068] or claim 18 as published.

Furthermore, the Examiner is asked to recognize that it is not at all routine to enable the lowering of the substrate temperatures while maintaining the growth rate. We would like to draw the Examiner's attention to the fact that achieving a high growth rate while lowering the substrate temperature and at the same time growing a layer with constant Germanium concentration and also a degree of relaxation of at least 75% is a method that is dependent on a multitude of highly interdependent parameters, and the choice of the parameters according to the present invention requires considerably more than routine skill in the art.

The step from high-temperature growth of thick, graded buffer layers to thin buffer layers grown at temperatures below 500°C is not, however, obvious, nor is it obvious that high growth rates can be maintained upon lowering the temperature, nor is it obvious that a high degree of relaxation can be achieved in this way.

Finally, the specific parameters of the annealing step are also not disclosed in any of the prior art documents. The annealing step is considered to be essential in order to achieve an increased degree of relaxation.

Consequently, it is believed that the amended claims are in condition for allowance. Acknowledgment of this fact is respectfully requested.

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Conclusion

Applicant has made a diligent effort to advance the prosecution of this application by cancelling claims, by amending claims, and by pointing out herein with particularity how the claims now presented are patentably distinct from the prior art of record. Therefore, Applicant respectfully submits that the claims, as amended, are now in condition for allowance. No new matter has been entered by this amendment. Any limitations to the claims are made without prejudice and solely for the purpose of expediting the prosecution of the application. Unless otherwise expressly stated, the amendments are not made to narrow, vis-à-vis the prior art, the scope of protection which any subsequently issuing patent might afford. Again, if the Examiner has further questions, she is invited to contact the undersigned at phone 011-4171-230-1000, fax at 011-4171-230-1001 (Switzerland is 6 hours ahead of Eastern Std Time), or e-mail at moetteli@patentinfo.net.

Applicant petitions the Commissioner for an Extension of Time under 37 CFR §1.136 for a period of ___X____ month and the Undersigned authorizes the Commissioner to charge any fee or credit any overpayment of any fee under 37 CFR §1.16 and §1.17 which may be required in this application to the deposit account of MOETTELI & ASSOCIES SARL, no. 50-2621.